PRINCIPIA **28**(4): 659–678 (2024) doi: 10.5007/1808-1711.2024.e96054
Published by NEL — Epistemology and Logic Research Group, Federal University of Santa Catarina (UFSC), Brazil.

PROJECTIBILITY AND SCIENCE: EPISTEMIC CHALLENGES

MOHAMMAD MAHDI HATEF
York University, CANADA
hatef@yorku.ca
https://orcid.org/0000-0003-3592-2788

Abstract. Appealing to science is a popular suggestion for separating projectible predicates. According to this suggestion, we can expect science, eventually, to separate such predicates for us, rendering it unnecessary to make further attempts to explicate the criteria for projectibility. In this essay, I address three theoretical challenges to this suggestion. The first stems from the inductive character of science, which casts doubts on its efficacy in separating projectible predicates, since induction itself requires this separation. The second is the inferential externalism implied by this suggestion, whereas the problems of induction have bite only if inferential internalism is presumed. The third challenge appears when a strong relationship between projectibility and kindhood, on the one hand, and kindhood and similarity, on the other, is posited, such that a more projectible predicate is believed to be a predicate which tracks better similarities in nature. Now the question appears: whether and how science enables us to track better similarities? I distinguish two conceptions of similarity, one intuitive, the other theoretical, and I argue that the theoretical one is to be preferred, showing that how scientific practice involves shifting from an intuitive idea of similarity to a theoretical one. Through answering these three challenges, I attempt to support the appeal to natural science as far as Goodman's problem of induction is concerned.

Keywords: projectibility • induction • similarity • natural kinds • scientific concepts

RECEIVED: 26/08/2023 REVISED: 22/10/2024 ACCEPTED: 01/11/2024

1. Introduction

Goodman's riddle poses an epistemic problem in regard to induction. He asks us to consider that there might be more than one hypothesis, each of which is equally confirmed by evidence, which can be used as the basis of an inductive generalization. 'Thus, the hypothesis 'All emeralds are grue', in his example, where a 'grue' object is one that is green if observed before *t* and blue thereafter, is equally as well confirmed by green emeralds observed before time *t* as is the hypothesis 'All emeralds are green'. The grue case is critical because the two rival hypotheses available from the inductive premises cannot both be true: since future emeralds would be green according to the first hypothesis, and blue according to the second. In other words, judgments made upon these hypotheses about future instances are incompatible, and so to make an inductive inference we must commit ourselves to using only one of these two predicates as the basis of the inference.

Goodman pointed out that there is no syntactical answer to this riddle; no syntactical facts can enable us to pick out one of the predicates and so privilege the inductions we make based upon it. In this sense, his riddle was a challenge to the theory of confirmation, an earlier proposal to solve the problems of induction.[1] In one of the first responses to this riddle, Carnap proposed a distinction between primitive properties (like green) and complex properties (like grue) (Carnap 1948). Appealing to a semantic distinction such as this revealed the failure of the theory of confirmation, as this theory would not be anymore a purely syntactical solution to the problem of induction. The real import of this riddle was then developed in Goodman's *Fact, Fiction, and Forecast*. After elucidating various consequences of the riddle, and the defects of suggested solutions, he proposed a novel answer. He underlined the distinction between projectible and non-projectible predicates and defined projectibility in terms of entrenchment in language.[2] Hence, for an inductive inference to be proper, it must have employed an adequately entrenched predicate in the language in which the generalization is made. Now, whether an induction is proper is contingent upon the language in which the predicates are incorporated; so while this indeed helps us escape the riddle, simultaneously it has two relativistic consequences. Epistemically, it challenges the reliability of inductive knowledge. Ontologically, it opens the way for radical ontological constructivism.

Goodman's suggestion was not the only semantic answer. By reintroducing the idea of natural kinds, Quine (1969) attempted to solve the riddle as well. Compared to Goodman's *linguistic* entrenchment, the naturalness of a kind was rendered by Quine as *cognitive* entrenchment. Accordingly, the predicates or kind terms proper for induction are taken to be those built upon *spacings of qualities* that are evolutionarily entrenched in our cognition. In addition to these two answers, there is also a third, which can be conceived as a third way for explicating the idea of the entrenchment of a predicate or kind term, according to which an entrenched term is a predicate or kind term whose corresponding property or kind is a part of the structure of the world. According to this *realist* approach, entrenched predicates or kind terms are those which 'carve nature at its joints', and are associated with causal powers (Elder 1990; Kornblith 1995; Boyd 1995).[3]

Accordingly, we have three notions of entrenchment in play: entrenchment in language, entrenchment in cognition, and entrenchment in the world. Of course, it is not the case that the two first entrenchments are entirely dissociated from the world: language, as underlined by Goodman, and cognition, as underlined by Quine, are evolutionary products that emerge through interaction with the world and were gradually shaped under selection pressures. The demands of nature would then have left traces in every aspect of these products (Goodman 1955, p.121). Nonetheless, the appeal to language and cognition leaves some distance between our inductions and the world. This distance, in Goodman's suggestion, stems from a certain tendency to suppose that there is a one-to-one correspondence between predicates and properties: the idea, known as the *abundance theory of properties*, that for every predicate there is a corresponding property. Adherence to the abundance theory is precisely the reason why artificial predicates have ontological consequences. To reduce this gap between induction and the world, or between projectibility and realism, other philosophers appealed to a *sparse theory of properties*, according to which only a small subset of predicates has the capacity to refer to properties—a subset in which disjunctive, conjunctive, and negative predicates are not included. As Lewis pointed out, "they carve at the joints, they are intrinsic, they are highly specific, the sets of their instances are *ipso facto* not entirely miscellaneous" (Lewis 1986, p.60).

In order to work, the sparse theory, and the above-mentioned views on entrenchment, all require some kind of discrimination among predicates: in Goodman's version, between projectible and non-projectible (in later terminology, genuine and artificial) predicates, and in other versions, between natural and non-natural predicates. There is, nevertheless, an essential difference between these two versions. The criteria for separating projectible or genuine predicates and kinds put forward by linguistic or cognitive accounts are accessible to us, for entrenchment in our language or cognition can be recognized via the linguistic or cognitive study. But the criteria put forward by a realist account, namely entrenchment in the world, is beyond our immediate access. Then, one way to develop the realist account is to explicate the criteria for realist entrenchment; a more common way, however, is to regard entrenchment in the world as primitive (Quinton 1957; Lewis 1984) and to introduce a referential framework able to distinguish between extensions of these predicates and kind terms themselves. As one may expect, the principal candidate for this referential framework is natural science, to which most philosophers of the natural kind tradition have appealed. Whereas Locke (1975 [1690]) referred to chemistry (Kornblith 1995, p.17), and Mill gave examples from biology (Mill 1974 [1843]), Lewis expected physics to discover the natural properties and kinds: "Physics discovers which things and classes are the most elite of all" (Lewis 1984, p.228).

Note that the issue is not that of identifying projectible predicates with scientific predicates, but that rather natural science is expected, eventually, to identify the projectible and non-projectible predicates.[4] Such an expectation is usually viewed as obvious, especially if natural kinds are deemed to be the very joints of nature. The appeal to science, nonetheless, is not free of epistemic challenges. In what follows, three challenges will be discussed in order to see whether natural science can be legitimately appealed to rule out the 'gruesome' Goodmanian predicates. In fact, we want to see whether appealing to science can plausibly separate projectible predicates, in such a way as not to make projectability dissociated from the structure of the world, or natural kinds. The first two challenges are epistemic in their nature and appear in any suggestion for a solution to the riddle which appeals to natural science. The third challenge, however, appears specifically with respect to the realist suggestion which connects projectibility to entrenchment in the world.

2. A challenge from inductive science

The new riddle of induction revealed that an inductive generalization requires some sort of discrimination among predicates, and that only a subset of predicates is deemed eligible to underlie an inductive inference. But now one may ask how natural science can be expected to pick out the predicates appropriate for induction, when it is itself inductive. To put this more clearly, induction requires some sort of discrimination between projectible predicates and non-projectible ones, and it is this discrimination that we expect natural science to effect; yet natural science is itself inductive and so its success presupposes that this discrimination has already been effected.

Some, following Quine (1969) who denied the priority of the philosophical problem of induction over the presumption of the success of natural science, have responded to this challenge in a naturalistic way.[5] Following Popper, who denied the crucial role usually assigned to inductive inference in scientific methodology, others have responded in a non-naturalistic way. Here I pass over these attempts and their difficulties to focus on another naturalistic response, based on Tversky and Kahneman's study of induction. Having shown that this response cannot help us escape the circularity, I then propose my own suggestion.

According to Tversky and Kahneman, inductive generalization is reliable thanks to the law of large numbers, which "guarantees that very large samples will indeed be highly representative of the population from which they are drawn" (Tversky & Kahneman 1982 [1971], p.25). Yet, they interestingly observed that we apply this law not only in cases with large numbers of samples, but also with small numbers, in order to make an inference based on limited instances. Godfrey-Smith (2011) provided examples of such an inference in science: in discovering the charge of an electron, Robert Millikan's experiments did not go beyond a relatively small number of oil drops, whereas his conclusion covered all electrons—presumably, in all the cosmos and for all time. And Chargaff, in discovering the rules regarding the composition of DNA, such that the amount of cytosine is the same as the amount of guanine, and the amount of thymine is the same as the amount of adenine, proposed this rule as covering all DNA even though his sample consisted only of nine types of organism.

These cases show that at least some seemingly inductive inferences in science are not ordinary inductions, at least in the sense that the law of large numbers does not apply in these cases. Now one may ask whether these inferences are inductive even in a non-ordinary sense, or whether they are not inductive at all. Pust (1996) argued for the latter, seeking to demonstrate that these inferences are deductive yet enthymematic, the invisibility of the implicit premise giving them a strange surface form. But a more important question is whether these inferences are justified. This question is essential because some crucial inferences in natural science are of such a form.

In his analysis of these inferences, Kornblith (1995) admitted that the rule followed in them differs from the rule followed in ordinary inductions. However, he does not hold that this rule is not applicable whatsoever. Like any other inferential rule, it is applicable only if certain conditions are in place. An applicability condition for this rule, according to him, is uniformity in the population:

> when a population is uniform with respect to some property, inferences from small samples, and indeed, from a single case, are perfectly reliable. If I note that a sample of copper conducts electricity and straightway conclude that all copper conducts electricity, then I will do just as well as someone who insists on checking a very large number of copper samples for their conductivity. (Kornblith 1995, p.92–93)

To summarize, when the sample is a member of a supposed natural kind with some kind properties, this rule is applicable. On this basis, along with ordinary inductions, inferences based on limited instances can be regarded as reliable. Accordingly, some of our scientific inferences which were supposed to be inductive come out to be non-inductive: they are indeed reliable, although their applicability depends on some requirement regarding natural kinds. The suggestion, therefore, reveals that induction has been overrated in the scientific method. Yet this suggestion, because of its dependence on natural kinds, fails to help us escape the initial circularity: for we were looking for an idea of scientific inference which does not require any kind of discrimination in terms of natural kinds or of projectibility.

The best way to escape this circularity might not be connected with scientific methodology, but rather with our attitude towards scientific kinds. In other words, the fact that science can introduce projectible or natural kinds may not be something that can be supported by reflection upon scientific methodology itself. Rather, these are philosophical arguments, e.g., arguments proposed for scientific realism, that allow us to conceive some kinds as representing the 'joints' of nature, whereas scientific methodology does not provide sufficient evidence for their reality. It is widely admitted that theoretical (non-observational) kinds in science are formed through contributions by scientists and are highly affected by their intentionalities. Hence, there is no guarantee, *prima facie*, that these kinds will correspond to real kinds in the world, at least when compared to observational kinds, concerning which a scientist is more passive. But how can theoretical kinds be real at the same time as depending on human intentionalities?

The answer lies in the nature of their dependence. The dependence of theoretical kinds on our intentionalities is causal, rather than constitutive, as our intentionalities contribute only to the formation of these kinds, while their permanence and function do not depend on us in any way.[6] If this dependence had been constitutive, as it is in social kinds, believing in their reality would be implausible; for example, knowing that the existence and function of money is indeed constitutively dependent on human intentionality (Searle 1995, Thomasson 2003, Khalidi 2013), few people are inclined to attribute independent reality to it. Nonetheless, the existence and function of quarks are supposed to be entirely independent of us and our intentions. As evidence for this independence, we may cite the conversions of some theoretical kinds into observational ones, like atoms or genes, through the advancement of experimental tools, in many circumstances in the history of science, conversions which seem impossible with respect to social kinds which are essentially intentional. Thus, the fact that kinds introduced by science can be admitted as natural or projectible is in no way related to scientific methodology, whether inductive or not.

It is worth noting that this suggestion is plausible insofar as the argument proposed for scientific kind realism does not depend on induction. If the "no miracle argument" is appealed to, for instance, inference to the best explanation (IBE) must be shown to be independently warranted.[7] But if IBE is dependent on induction in one way or another,[8] there will be another circularity, as we have relied on inductive support to solve a problem of induction.

3. A challenge from inferential internalism

Appealing to science to solve Goodman's riddle of induction may be challenged in another respect. The problems of induction make sense only within the context of inferential internalism, while appealing to natural science and its reliability seems to imply a commitment to inferential externalism. Hence, embracing natural science to solve the problem of induction seems incoherent.

To the externalist, the justification of an inference hinges on plausibly presuming the reliability of an inference form which it instantiates. Thus, the reliability of an inferential process is all we need in order to accept its conclusion as justified. In Goldman's terms, "If *S*'s belief in *p* at *t* is a product of a reliable cognitive belief-forming process (or set of processes), then *S*'s belief in *p* at *t* is justified" (Goldman 1979, 97). To the internalist, however, justification is a different matter. To him, the reliability of an inferential process does not suffice for its conclusion to be justified. As Fumerton pointed out, "the inferential internalist holds that inferential justification involves 'seeing' the appropriate connection between one's premises and what one infers from those premises" (Fumerton 2006, p.101). In other words, it is essential to the internalist that it is made clear what it is in an inferential process that fills the gap between premises and conclusion.

It is precisely on this basis that internalists have engaged with Carroll's paradox of Achilles and the Tortoise (Carroll 1895) and hoped to find a solution. Carroll's paradox is principally concerned with deductive inference. Nonetheless, the same issue can be raised as regards induction so as to cast doubt on the rule through which inductive inference proceeds. From this point of view, inductive success is insufficient for an inference to be regarded as justified, and it is necessary to answer the further question of how an inference establishes its conclusion. Now, the issue is that Goodman's riddle causes trouble only within such a framework. Similarly, other problems of induction, like Hume's or Hempel's paradox, can be framed only within an internalist framework.[9] Hence, the externalist responses to renowned induction problems are likely to be answers to a different question. The science-based response to Goodman's problem might seem like an externalist response and vulnerable in exactly this respect, because what helps us escape the riddle is a kind of trust in science and a reliance on the validity of discriminations it poses among kinds. In this manner, no reference is made to the internal structure of induction, and the problem is solved thanks to our prior trust in science.

It is a truism that the disagreement between inferential internalism and externalism issues from their concern with the rationality of inductive inference. However, it is not clear that Goodman's problem touches upon this rule. This will be clear when we concentrate on the difference between Goodman's problem and Hume's problem. Hume's problem directly targets the rationality of the inferential rule, and casts doubt upon the inference from inductive premises to a general conclusion; Goodman's riddle, however, seems to presuppose the rationality of the inductive rule and questions the conditions for an appropriate inductive hypothesis. To illuminate this further, let us sketch the science-based response to the riddle:

– A proper induction is one based on genuine (natural) predicates.

– Genuine (natural) predicates are provided by science.

Hence, a proper induction is one that is based on the predicates provided by science.

What is illustrated by this sketch is that the appeal to science is not intended to bestow rationality to the inferential rule itself; rather, the appeal is aimed at justifying the second premise, which says that the suitable predicates or natural kinds are the scientific predicates or kinds. This solution indeed relies on trust in science. Nevertheless, what is trusted is not an inferential rule, but one of the premises of the inference. It follows that Goodman's riddle does not touch the debate on inferential internalism/externalism; it is, one might say, downstream of that debate.[10]

4. A challenge from similarity

As argued earlier, to separate the projectible predicates (or kind terms) from the non-projectible ones is, in many interpretations, to separate the genuine or natural predicates (or kind terms) from the non-genuine or non-natural ones. This is because, to put it in Quine's terms, "a projectible predicate is one that is true for all and only the things of a kind" (Quine 1969, p.116). Connecting projectibility to kinds, however, also associates it to similarity, as instances of a kind are taken to be those with the highest resemblance.[11] The problem of projectibility is accordingly connected to the problem of similarity. Quine was explicit on the dependence of projectibility on similarity. If you ask "why we expect the next one to be green rather than grue?" he says, "the intuitive answer lies in similarity" (ibid.). Then, pace Goodman, who took entrenchment in language as the basis for projectibility, Quine based projectibility, along with a large number of cognitive affairs, on similarity: "a sense of similarity or of kinds is fundamental to learning in the widest sense—to language learning, to induction, to expectation" (129). William James had even gone further, to argue that "this sense of Sameness is the very keel and backbone of our thinking" (James 1950 [1890], p.459). Now, similarity is widely believed to be the basis for a variety of cognitive activities: it is argued that retrieved items cue the subsequent retrieval of similar items (Bousfield & Sedgewick 1944; Romney, Brewer, & Batchelder, 1993; Howard & Kahana 2002;); that objects are categorized based on their similarity to an exemplar category (Medin & Schaffer 1978; Nosofsky 1986, 1992) or a prototype category (Posner & Keele 1968; Rosch & Mervis 1975); that learning concepts is highly improved by grouping more similar instances of a given concepts (Weitnauer, et al., 2014); that abstract higher order-thinking hinges on the capacity to perceive relational similarity (Gentner 2003; Gentner & Hoyos 2017); that decisions are made based on the similarity between a state resulting from the choice and an ideal state (Medin, Goldstone, & Markman 1995); and that strategies used in past problems are employed in problems which are similar to the former (Bassok 1990; Novick 1988, 1990). The strength of an inductive argument depends on the similarity between the target of the argument and the base of the argument (Osherson et al. 1990).[12]

When we argue that green is more projectible than grue, because green objects are more alike than grue objects, we are indeed arguing that, based on certain intuitions we have about similarity, green objects look more alike than grue objects. In other words, regarding the problem of induction, we employ a subjective idea of similarity, which bases our 'spacings of qualities' on 'innate standards of similarity', to use Quine's words. In the case of grue vs. green, or every artificial predicate, including negative, conjunctive, and disjunctive ones, vs. *primitive* predicates (in Carnap's terms), these innate standards of similarity speak in favor of the second ones. This is why Quine refers to these intuitive standards in order to distinguish the predicates appropriate for induction.

It is a truism that our cognition highlights certain similarities to employ them in cognitive activities and underestimates other similarities. For example, it highlights the difference in skin color, more than location, of two similar animals observed during the practice of kinding; when it comes to leaves, however, it highlights the difference in place more than the size of two leaves, where one, for example, is observed on top of a tree, and the other in a bush. Kinds that are unconsciously formed in our cognition are presumably formed based on similarity relations embedded in it. Then, the crucial question is to which extent kinds that are formed according to these similarities match the joints of nature. In other words, to what extent do the projectible kinds that these similarity relations point towards correspond to the natural kinds? This question is essential, as our best scientific kinds that supposedly underlie inductions are supposed to be well-entrenched in the world.[13] They are expected to associate with natural kinds in one way or another (Elder 1990), such that laws resulting from their generalizations are related to the laws of nature (Jackson & Pargetter 1980). [14]

One might suggest that the evolutionary history of these similarities is good evidence that they match natural kinds. In other words, following Dennett (1987) and Fodor (1981), who associate natural selection with the truth and rationality of our beliefs, one may appeal to natural selection to support the idea that the similarities and kinds encouraged by our cognition are likely in line with joints of nature. But evolutionary history is supposed to celebrate the survival-tracking character of these similarities, not their truth-tracking character, and there is no reason for the former to associate with the latter (Stein, 1996, p.260–28; Baghramian 2004, p.13). Furthermore, intuitive similarities are constituted through our ordinary perceptions of medium-sized objects and events, while philosophers of natural kinds, since Locke, have been inclined to suppose that the best instances of natural kinds are those based on underlying micro-structural boundaries rather than superficial sensible ones.

Therefore, it seems that there is a motivation for pessimism about our similarity intuitions when it comes to scientific kinding. This pessimism is intensified when we investigate these intuitions more closely. In the following, I list some of these intuitions. Based on experimental studies, it is found that:

1- "people attend more to common features in judgments of similarity, than in judgments of difference" (Tversky & Gati 1978, p.81).

2- "The relative importance of attributes and relations shifts substantially depending on whether similarity or difference judgments are being made, with relations being more attended to in similarity judgments and attributes more attended to in difference judgments" (Medin et al. 1990, p.66).

3- "We tend to select the more salient stimulus, or the prototype, as a referent, and the less salient stimulus, or the variant, as a subject... We say "an ellipse is like a circle," not "a circle is like an ellipse" (Tversky 1977, p.328).

4- Recognizing similarity between two objects is sometimes easier than identifying one object. For example, "two different letters may be more similar to each other than a particular letter is to itself. The letter C is more similar to the letter O than W is to itself, as measured by interletter confusions" (Goldstone & Son 2005, p.18).

5- The "[f]olk impulse to classify biological kinds is driven by practical rather than intellectual considerations, and ... the utilitarian features of organisms (those most directly affecting the use of the plant or animal) are of primary interest to folk classifiers" (Hunn 1982).

6- The "salience" of respects of similarity (or features of similarity) in terms of which similarity is measured is of great importance in similarity judgments. This salience is affected by many factors, including intensity, frequency, familiarity, good form, and information, all of which are subject-oriented (Tversky & Gati 1978).

7- Visual perception has a particular structure according to which topological similarities are more crucial than similarities in shape (Chen 1982).

These findings, revealed by studying our similarity judgments, are among the characteristics of our intuitive idea of similarity. What is crucial is that these characteristics are partially *opposed* to our theoretical idea of similarity. By our theoretical idea of similarity, I mean an idea which is present in theoretical as opposed to intuitive thinking, and is broadly employed in theoretical practices in science.[15] For example, findings 1 and 2 violate the presupposition of the theoretical idea of similarity that similarity and difference judgments are logical opposites (Medin et al. 1990), a presupposition which was also expressed by James Mill when he said, "distinguishing differences and similarities is the same thing; a similarity being nothing but a slight difference" (Mill 1829, p.13–14). Finding 3 stands opposed to the symmetry of similarity (Tversky 1977), which implies that the similarity (or difference) of a to b equals the similarity (or difference) of b to a. Finding 4 violates the minimality axiom (ibid.), which implies that everything is more similar to itself than to anything else. Findings 5, 6, and 7 violate the conventional view in theoretical approaches to similarity that the more underlying and foundational a feature of similarity is, the more significant it is (Kemp et al. 2005). This is an objective judgment independent of our prior familiarity with these features or their practical utilities. I do not claim that the intuitive idea of similarity is entirely opposed to the theoretical one. This might indeed not be the case whatsoever, considering the evolutionary history of intuitive similarity and the cognitive origins of both ideas. My points are that the differences between two ideas must be considered and that our intuitions do not track the best idea of similarity.

It is a truism that a difference between an intuitive idea, which is revealed in particular cases, and a theoretical one, which is deliberately articulated, is not unanticipated. Cognitive studies are replete with cognitive biases with no epistemic justification. There are also numerous examples of arguments that are intuitively plausible but violate the rules of logic, statistics, and probability.[16] These cases are of importance to cognitive scientists, as they shed light on our innate cognitive activities, but of not much importance to the scientists who use these mathematical and logical rules. A deliberative theoretical idea that people have of these rules, rather than an intuitive idea which traces back to our practical animal needs, is a ground for employing them in scientific studies. This dichotomy also induces pessimism about innate intuitions of similarity, not as intuitions of practical life, but as axioms of similarity which underlie our thinking.[17] This pessimism encourages us to go beyond similarity intuitions as much as possible in scientific practice, and work with a more robust idea of similarity. This is exactly what we do in mathematics and logic, where the rules are based on advanced theoretical ideas.[18]

Philosophers who tend to be realist about natural kinds and at the same time expect science to identify elite kinds are presumably willing to work with kinds, or similarity relations, which are mind-independent and match the structure of the world as much as possible, rather than to reflect our subjective quality spaces.[19] Lewis had such an idea of scientific predicates and kind terms when pointing to elite kinds or joints of nature: “Only an elite minority are carved at the joints, so that their boundaries are established by objective sameness and difference in nature” (Lewis, 1984, p.227). Concentrating on theoretical aspects, rather than practical and utilitarian aspects, and deepening the similarities between objects, as marks of the advancement of science, are evidence for the fact that we tend to go beyond intuitive similarities during scientific practice.

This move from practical, utilitarian similarities to intellectual, speculative ones can be tracked both in science learning and the history of science.[20] In the case of taxonomy, for example, people are observed to be more interested in classifying biological kinds based on practical considerations rather than intellectual ones, where utilitarian aspects, which are connected to their applications, are of great interest to them (Hunn 1982, Shipman & Boster 2008). A change in similarities is also observed in the shift from apprentices to experts. According to Boster and Johnson (1989), while apprentices base their judgments on the morphological traits of fishes, experts appeal as well to ecological traits in setting similarity relations. In other fields of biology, even ecological differences do not persist and are replaced by more speculative similarities like similarities in terms of a common ancestor, reproductive similarities, or genetic similarities. This difference can also be observed between scientists and workers. According to Medin et al. (1997), taxonomists' sorting of trees is largely based on morphologies, while landscape workers sort trees based on utilitarian features (street trees, flowering trees, ornamental trees, weed trees). Similarly, while color had a significant role in the early classifications of elements (Kornblith 1995, p.51), this role is already replaced by atomic number in the periodic table. As opposed to color, about which we have familiar intuitions, atomic number is unlikely to be associated with our similarity intuitions. The fact that chemical classifications are based on this feature, rather than, for example, on the mass number, is associated as well with certain theoretical interests we have in chemistry, according to which the reactivity of an element depends on its atomic number.

This shift is also reflected in Kuhn's distinction between scientific concepts. He puts the concepts with which we deal in science into two groups: first, normic concepts which are learnt through ostension, and are ordinarily applied through direct inspection. These concepts build on similarities and dissimilarities, and are acquired together in contrast sets. An example would be the concept of fluid, which is learned in contrast to solids and gas. Kuhn (1977 [1974]) and others (Carey 1992, Andersen & Nersessian 2000, Andersen et al. 2006) saw continuity between these concepts and ordinary concepts and held that the mechanisms responsible for the formation, learning, and employing these concepts are the same as for ordinary concepts. This continuity is good evidence for the fact that conceptualization in this context is influenced by our intuitions of similarity. But there is another type of concepts which does not build on similarity relations and does not form contrast sets. Kuhn's favored theoretical concepts, namely mass and force, are among them, which are conceived and acquired through interdefined vocabulary clusters, rather than contrast concepts. These concepts, which Kuhn called nomic concepts, are obviously dominant in more theoretical sciences such as physics.

The advancement of science has been accompanied by shifts from the first group of concepts or kinds to the second. Unlike the first group, the second are non-similarity class concepts. They are introduced in problem situations and defined within the laws of nature. It may support this judgment that these concepts go beyond our similarity intuitions. Nonetheless, Andersen and Nersessian (2000) attempted to define another form of similarity classes for these concepts: a similarity that holds, not between individual concepts, but between problem situations in which these concepts appear. According to them, the problem situations within which these concepts are defined and employed stand in relations of family resemblance to each other. As Goldstone and Son (2005) pointed out, if a cue is similar enough to a stored memory, the memory may be retrieved (Raaijmakers & Shiffrin 1981), or if an unknown object is similar enough to a known object, then the known object's category label may be applied to the unknown object (Nosofsky 1986); in the same way, if a problem is similar to a previously solved problem, then the solution to the old problem may be applied to the new problem (Holyoak & Koh 1987; Ross 1987 1989).

What is less commonly noticed in this account is that problem situations have a mathematical nature and are entirely different from the objects of perception. It is not clear that some of our similarity intuitions which are built to deal with ordinary objects can be applied to the mathematical entities. For example, Andersen and Nersessian (2000) characterized problem situations associated with electrostatic action in terms of charge distribution, electric field, electric action, and electrostatic potential, with different values for each one. Charge distribution, for instance, takes different values as regards point charge, line charge, and surface charge. It is not clear how some of our similarity intuitions can apply to these concepts and values, nor in the problem situations that are characterized by them. The entities involved in such problem situations mostly have a mathematical nature, and therefore lie further from our intuitions and possess no ostensible quality. This might be interpreted as evidence supporting the fact that theoretical work in science is such that it makes shifts from intuitive similarities to theoretical ones unavoidable.[21]

One may think that noticing the role of models in scientific theories opens up more room for intuitive similarities, as representing mathematical entities in models is largely accompanied by ontological interpretations, which are more accessible to our perceptions. This might be true of concrete models, namely physical objects whose physical properties can potentially stand in a representational relation to real world phenomena (Weisberg 2013), like the particle model for electrons, Watson-Crick's model for DNA, or the San Francisco Bay Delta model. In mathematical or computational models, however, it is far from true. By mathematical models I mean abstract structures whose properties can stand in relations to the mathematical representation of the phenomena, like the Lotka-Volterra model for rate changes in populations of prey and predator. By computational models, I mean procedures that can stand in relations to a computational description of the system's behavior, like Schelling's micromotives and macrobehavior model, which illustrates how racial segregation can emerge in a population, even when no racism is present (ibid.). The mathematical or computational nature of these models rules out the application of the greater part of our similarity intuitions, and it opens up a space of contingency that allows theoretical similarities to participate more broadly in scientific practice.

Going beyond suspicious similarity intuitions and replacing them with theoretical similarities through scientific practice supports the view that kinds formed according to scientific similarities match more likely the joints of nature, and then inductions made by them track more likely the laws of nature.

5. Conclusion

In this essay, I addressed three epistemic challenges against the idea that appealing to science can legitimately separate projectible predicates and kind terms. In the first one, which stems from the inductive nature of the scientific method, I attempted to show that the projectibility of predicates and kind terms has nothing to do with scientific methodology. Terms introduced by science are projectible because there are philosophical arguments showing that their corresponding properties or kinds are natural. The second challenge stems from the fact that problems of induction make sense only in an inferential internalist framework, while this suggestion itself seems to be committed to a sort of inferential externalism. As I argued, despite its reliabilist character, this suggestion is indeed not committed to inferential externalism, and so is not vulnerable in this respect. The third challenge goes back to the problem of similarity, and the observation that our intuitive idea of similarity penetrates every cognitive practice, including the practice of kinding in science, whereas there is some evidence showing that these intuitions do not track the best similarities. I argued that scientific practice involves replacing this intuitive idea of similarity with a more deliberative idea to work with in scientific kinding. Furthermore, the mathematical nature of scientific concepts and models prohibits these intuitions from taking a substantial role in scientific practice.

References

Andersen, H.; Nersessian, N. 2000. Nomic concepts, frames and conceptual change. *Philosophy of Science* 67: 224–241.

Andersen, H.; Barker, P.; Chen, X. 2006. *The Cognitive Structure of Scientific Revolutions.* Cambridge: Cambridge University Press.

Baghramian, M. 2004. *Relativism*. London: Routledge.

Bassok, M. 1990. Transfer of domain-specific problem-solving procedures. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 16: 522–533.

Boster, J. S.; Johnson, J. C. 1989. Form or Function: A Comparison of Expert and Novice Judgments of Similarity Among Fish. *American Anthropologist* 91(4): 866–889.

Bousfield, W. A.; Sedgewick, C. H. W. 1944. An analysis of sequences of restricted associative responses. *Journal of General Psychology* 30: 149–165.

Boyd, R. 1995. Homeostasis, species and higher taxa. In R. Wilson (ed.), *Species*, p.141-185. Cambridge, MA: MIT Press.

Carey, S. 1992. The origin and evolution of everyday concepts. In R. N. Giere (ed.), *Cognitive Models of Science*, p.15-89. Minnesota Studies in the Philosophy of Science, Vol. XV. Minneapolis: University of Minnesota Press.

Carey, S.; Spelke, E. 1996. Science and core knowledge. *Philosophy of Science* 63(4): 515–533.

Carnap, R. 1948. Reply to Nelson Goodman. *Philosophy and Phenomenological Research* 8(3): 461–462.

Carroll, L. 1895. What the tortoise said to Achilles. *Mind* 4(14): 278–280.
Chang, H. 2015. The rising of chemical natural kinds through epistemic iteration. In C. Kendig (ed.), *Natural Kinds and Classification in Scientific Practice*, p.33–47. London: Routledge.
Chen, L. 1982. Topological structure in visual perception. *Science, New Series* 218(4573): 699–700.
Conee, E.; Feldman, R. 2008. Evidence. In Q. Smith (ed.), *Epistemology: New essays*, p.83–104. Oxford: Oxford University Press.
Cowling, S. 2017. Resemblance. *Philosophy Compass* 12(4): e12401.
Dennett, D. 1987. *The Intentional Stance.* Cambridge. MA: MIT Press.
Elder, C. 1990. Goodman's New Riddle – A Realist Reprise. *Philosophical Studies* 59(2): 115–135.
Ereshefsky, M.; Reydon, T. A. C. 2015. Scientific kinds. *Philosophical Studies* 172(4): 969–986.
Fodor, J.A. 1981. *Representations: Philosophical Essays on the Foundations of Cognitive Science.* Cambridge, MA: MIT Press.
Foster, J. 1983. Induction, explanation and natural necessity. *Proceedings of the Aristotelian Society* 83: 87–101.
Frege, G. 1964 [1883]. *The Basic Laws of Arithmetic: Exposition of the System*. Trans. and ed. M. Furth. Berkeley: University of California Press.
Fumerton, R. 1980. Induction and reasoning to the best explanation. *Philosophy of Science* 47: 589–600.
Fumerton, R. 2006. *Epistemology*. Oxford: Blackwell.
Gärdenfors, P. 2000. *Conceptual Space: The Geometry of Thought*. Cambridge, MA: MIT Press.
Garner, W. R. 1974. *The processing of information and structure*. New York: Wiley.
Gentner, D. 2003. Why we're so smart. In D. Gentner; S. Goldin-Meadow (eds.), *Language in Mind: Advances in the Study of Language and Thought*. p.195–235. Cambridge, MA: MIT Press.
Gentner, D; Hoyos, C. 2017. Analogy and abstraction. *Topics in Cognitive Science* 9: 672–693.
Giere, R. N. 1990. textitExplaining Science: A Cognitive Approach. Chicago: University of Chicago Press.
Godfrey-Smith, P. 2003. Goodman's problem and scientific methodology. *The Journal of Philosophy* 100(11): 573–590
Godfrey-Smith, P. 2011. Induction, samples and kinds. In J.K. Campbell et al. (eds.) *Carving Nature at Its Joints*, pp.33–53. Cambridge, MA: MIT Press.
Goldman, A.I. 1979. What is justified belief?, in G. S. Pappas (ed.), *Justification and Knowledge. Philosophical Studies Series in Philosophy*, 17, p.1–25. Dordrecht: Springer.
Goldstone, R. L. 1994. Similarity, interactive activation, and mapping. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 20: 3–28.
Goldstone, R. L.; Son, J. Y. 2005. Similarity. in K. Holyoak; R. Morrison (eds.), *The Cambridge Handbook of Thinking and Reasoning*, p.13–36. Cambridge: Cambridge University Press.
Goodman, N. 1951. *The Structure of Appearance*. Cambridge, MA: Harvard University Press.
Goodman, N. 1955. *Fact, Fiction and Forecast.* Cambridge, MA: Harvard University Press.
Harman, G. 1965. The Inference to the Best Explanation. *Philosophical Review* 74: 88–95.
Holyoak, K. J.; Koh, K. 1987. Surface and structural similarity in analogical transfer. *Memory and Cognition* 15: 332–340.

Howard, M. W.; Kahana, M. J. 2002. When does semantic similarity help episodic retrieval?. *Journal of Memory and Language* 46: 85–98.

Hunn, E. 1982. The Utilitarian Factor in Folk Biological Classification. *American Anthropologist* 84(4): 830–847.

Jackson, F. 1975. Grue. *Journal of Philosophy* 72(5): 113-131.

Jackson, F.; Pargetter, R. 1980. Confirmation and the Nomological. *Canadian Journal of Philosophy* 10: 415–28.

James, W. 1950 [1890]. *The principles of psychology.* New York: Dover.

Kahneman, D. 2011. *Thinking fast and slow*. New York: Farrar, Straus and Giroux.

Kemp, C.; Bernstein, A.; Tenenbaum, J. B. 2005. A generative theory of similarity. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 27. https://escholarship.org/uc/item/66b344s3. Access 08.11.2024.

Khalidi, M. A. 2013. Three kinds of social kinds. *Philosophy and Phenomenological Research* 90: 96–112.

Kornblith, H. 1995. *Inductive inference and its natural ground.* Cambridge, MA: MIT Press.

Kuhn, T. 1977 [1974]. Second Thoughts on Paradigms. In *The Essential Tension*, p.293–319. Chicago: University of Chicago Press.

Lewis, D. 1984. Putnam's Paradox. *Australasian Journal of Philosophy* 62(3): 221–236.

Lewis, D. 1986. *On the Plurality of Worlds*. Oxford: Blackwell.

Locke, J. 1975 [1690]. *An Essay concerning Human Understanding.* Edited by P. H. Nidditch. Oxford: Oxford University Press.

Lycan, W. G. 1988. *Judgement and justification.* Cambridge: Cambridge University Press.

Magnus, P.D. 2012. *Scientific Inquiry and Natural Kinds*. London: Palgrave Macmillan.

Markman, A. B.; Gentner, D. 1993. Structural alignment during similarity comparisons. *Cognitive Psychology* 25: 431–467.

Medin, D. L.; Goldstone, R. L.; Gentner, D. 1990. Similarity Involving Attributes and Relations: Judgments of Similarity and Difference are not Inverses. *Psychological Science* 1(1): 64–69.

Medin, D. L.; Goldstone, R. L.; Markman, A. B. 1995. Comparison and choice: Relations between similarity processes and decision processes. *Psychonomic Bulletin and Review* 2: 1–19.

Medin, D. L.; Schaffer, M. M. 1978. Context theory of classification learning, *Psychological Review* 85: 207–238.

Medin, D. L; et al. 1997. Categorization and Reasoning among Tree Experts: Do All Roads Lead to Rome? *Cognitive Psychology* 32(1): 49–96.

Mill, J. 1829. *Analysis of the phenomenon of the human mind (Vol. 2).* London: Baldwin and Cradock.

Mill, J. S. 1974 [1843]. *A System of Logic, Ratiocinative and Inductive, Part II*. Toronto: University of Toronto Press.

Morton, A. 1975. Complex individuals and multigrade relations. *Nous* 9: 309–318.

Murphy,G. L.; Medin,D. L. 1985. The role of theories in conceptual coherence. *Psychological Review* 92: 289–316.

Nosofsky, R. M. 1986. Attention, similarity, and the identification-categorization relation. *Journal of Experimental Psychology, General* 115: 39–57.

Nosofsky, R. M. 1992. Exemplar-based approach to relating categorization, identification, and recognition. In F.G. Ashby (ed.), *Multidimensional models of perception and cognition*, p.363–394. Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Novick, L. R. 1988. Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology, Learning, Memory, and Cognition* 14: 510–520.

Novick, L. R. 1990. Representational transfer in problem solving. *Psychological Science* 1: 128–132.

Osherson, D. N.; et al. 1990. Category-based induction. *Psychological Review* 97: 185–200.

Posner, M. I.; Keele, S. W. 1968. On the genesis of abstract idea. *Journal of Experimental Psychology* 77: 353–363.

Pust, J. 1996. Induction, Focused sampling, and the law of small numbers. *Synthese* 108: 89–104.

Quine, W. V. 1969. Natural Kinds. in *Ontological Relativity and Other Essays*. New York: Columbia University Press.

Quinton, A. 1957. Properties and Classes. *Proceedings of the Aristotelian Society* 58: 33–58.

Raaijmakers, J. G. W.; Shiffrin, R. M. 1981. Search of associative memory. *Psychological Review* 88: 93–134.

Romney, A. K.; Brewer, D. D.; Batchelder, W. H. 1993. Predicting clustering from semantic structure. *Psychological Science* 4: 28–34.

Rosch, E. 1973. Natural categories. *Cognitive Psychology* 4: 328-350.

Rosch, E.; Mervis, C. B. 1975. Family resemblance: Studies in the internal structure of categories. *Cognitive Psychology* 7: 573–605.

Ross, B. H. 1987. This is like that: The use of earlier problems and the separation of similarity effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 13: 629–639.

Ross, B. H. 1989. Distinguishing types of superficial similarities: Different effects on the access and use of earlier problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 15(3): 456–468.

Searle, J. 1995. *The Construction of Social Reality*. New York: The Free Press.

Shafir, E.; Smith, E.; Osherson, D. 1990. Typicality and reasoning fallacies'. *Memory and Cognition* 18(3): 229–239.

Shepard, R. N. 1962a. The analysis of proximities: Multidimensional scaling with an unknown distance function. Part I. *Psychometrika* 27: 125–140.

Shepard, R. N. 1962b. The analysis of proximities: Multidimensional scaling with an unknown distance function. Part II. *Psychometrika* 27: 219–246.

Shipman, A. S.; Boster, J. S. 2008. Recall, Similarity Judgment, and Identification of Trees: A Comparison of Experts and Novices. *Ethos* 36(2): 171–193.

Slater, M. 2015. Natural Kindness. *British Journal for the Philosophy of Science* 66(2): 375-411.

Sloman, S. A. 1996. The empirical case for two systems of reasoning. *Psychological Bulletin* 1(19): 3–22.

Smith, E. E.; Sloman, S. A. 1994. Similarity versus rule-based categorization. *Memory and Cognition* 2(2): 377–386.

Spelke, E. S. 1988. The origin of physical knowledge. In L. Weiskrantz, (ed.), *Thought without Language*. Oxford: Oxford University Press.

Stein, E. 1996. *Without Good Reason.* Oxford: Oxford University Press.

Thomasson, A. 2003. Realism and Human Kinds. *Philosophy and Phenomenological Research* 67: 580–609.

Tversky. A. 1977. Features of Similarity. *Psychological Review* 84: 327–352.

Tversky, A.; Gati, I. 1978. Studies of similarity. In E. Rosch; B. Lloyd (eds.), *Cognition and Categorization*, p.79–98. Hillsdale, NJ: Erlbaum.

Tversky, A.; Kahneman, D. 1974. Judgment under Uncertainty: Heuristics and biases. *Science* 185: 1124–1131.

Tversky, A.; Kahneman, D. 1982 [1971]. Belief in the Law of Small Numbers. In D. Kahneman et al. (eds.), *Judgment under Uncertainty: Heuristics and Biases*, p.23–31. New York: Cambridge University Press.

Tversky, A.; Kahneman, D. 1982. Judgments of and by representativeness. In D. Kahneman et al. (eds.), *Judgment under Uncertainty: Heuristics and Biases*, p.84–98. New York: Cambridge University Press.

Tversky, A.; Kahneman, D. 1983. Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological Review* 90: 293–315.

Ullman, S. 1996. *High-level vision: Object recognition and visual cognition*. London: MIT Press.

Weintraub, R. 2013. Induction and inference to the best explanation. *Philosophical Studies* 166(1): 203–216.

Weisberg, M. 2013. *Similarity and Simulation: Using models to understand the world*. Oxford: Oxford University Press.

Whewell, W. 1858. *Novum organon renovatum: Being the Second Part of the Philosophy of the Inductive Sciences.* London: John W. Parker & Son, West Strand.

Notes

[1]Perhaps this is why Goodman's objection was at first underestimated, being considered a minor objection to the technical theory of confirmation.

[2]"Entrenchment derives from the use of language" (Goodman 1955, p.95).

[3]The answers mentioned here are semantic answers in regard of meaning of predicates. There are also interesting answers focusing on predication. See Jackson (1975, 1980), for example, and also Godfrey-Smith (2003), for an innovative version that attempts to solve Goodman's riddle employing statistical considerations.

[4]Connecting entrenchment in the world to science is not difficult, as it is already implied by the idea of natural kinds, realistically understood. Connecting entrenchment in the language to science is comparably more difficult, since there is no predicate entrenched in language for many theoretical entities. To solve this problem, Goodman (1955, p.97) attempted to distinguish entrenchment from familiarity. In a similar way, connecting entrenchment in cognition to science is not easy, as the entrenchment in cognition is a product of human evolutionary history, which is far from the content of theoretical science.

[5]Quine's response was epistemologically reliabilist, and like every other reliabilist response, commits us to inferential externalism. However, as will be pointed out in the next section, any answer to the riddle of induction needs to be framed within inferential internalism.

[6]For more discussion, see Kukla (2000), p. 21ff.

[7]As Harman (1965), Foster (1983), Lycan (1988), Conee&Feldman (2008), and Weintraub (2013) hold.

[8]As Fumerton (1980) holds.

[9]None of these philosophers casts doubt on the reliability (or success) of induction, while all of them challenge its justification.

[10]While Goodman's riddle does not directly address the rationality of induction, it does not imply that rationality is irrelevant to the riddle. For an instance to be considered a proper example of induction, we need a justified theory of induction, and developing such a theory inevitably touches questions of rationality.

[11]Before and after Quine (ibid.), Goodman (1951) and Morton (1975) attempted to define natural kinds in terms of similarity as well. In his attack on resemblance nominalism, in his "New work for a theory of universals," Lewis cast doubts on this approach and argued that the reverse, viz. to define similarity in terms of naturalness, also might be the case: "we might have taken N [naturalness] as primitive instead of R [resemblance]. But would that have been significantly different, given the interdefinability of the two?" (Lewis 1984, 348). In his essay "Putnam's paradox," however, he seems inclined to the above stance; to set the boundaries of natural kinds based on similarity: "Only an elite minority are carved at the joints, so that their boundaries are established by objective sameness and difference in nature" (Lewis 1986, p.227).

[12]A significant role assigned to similarity has been denied in some studies, though. For example, it is argued that categorization is frequently based on theories (Murphy & Medin 1985), rules (Sloman 1996; Smith & Sloman 1994), or strategies, which go beyond "mere" similarity.

[13]The above question gains in importance if we agree with Cowling that "views about the world's basic ontological categories bear directly upon the nature of fundamental resemblance facts" (Cowling 2017, p.6).

[14]Focusing on similarity relations embedded in our cognition and the world does not imply that I deny the significance of our background knowledge or language in the present proposals about what to project, as I clarified it in the first section. The current question is, setting aside that knowledge, how inherent similarity relations contribute to a realist view of the world.

[15]Such a distinction between intuitive and theoretical ideas of similarity judgments can also be found in Kahneman (2011), where system 1 thinks quickly and employs intuitive similarities, and system 2 thinks slowly and employs deliberative similarities.

[16]Logical examples are the renowned logical fallacies. For statistics and probability examples, see Tversky & Kahneman (1974, 1982, 1983) and Shafir et al. (1990).

[17]Interestingly, the same difference can be found between a theoretical view of natural kinds and an intuitive one. A theoretical view has traditionally been a definitional view which characterizes kinds in terms of necessary and sufficient conditions. In studies by Rosch and his colleagues (Rosch 1973; Rosch & Mervis 1975), however, it is found that people usually form, learn, and use kinds based on exemplars or prototypes, a fact which supported a type view of kinds. This type view was interestingly anticipated by some philosophers, most notably William Whewell (1858), though. But exactly for the theoretical reasons (applications of kinds in classification and induction) proposed by John Stuart Mill (1974 [1843]), Whewell's view was disregarded in nineteenth century.

[18]Note that the various models are used to represent similarity, including the geometrical model (Shepard 1962a, 1962b), featural model (Tvesrky, 1977), alignment-based models (Goldstone 1994a; Markman & Gentner, 1993a), and transformational models (Garner 1974, Ullman 1996) are all about the intuitive idea. In this respect, these models are of a different type from rules of probability or logic, as they are about our theoretical idea, and are described, in Frege's terms, as "laws of truth, and not natural laws of human beings" (Frege 1964 [1883], xvi); they are prescriptive laws with universal and absolute validity, opposed to descriptive laws contingent on our psychology.

[19]The view of kinds on which this essay is focused is an ontological view that approaches kinds from a realist perspective. The challenges addressed here presumably emerge from this view. Other views, like the epistemological one, which has been popularized during past decades (Boyd 1995; Magnus 2012; Chang 2015; Ereshefsky & Reydon 2015; Slater 2015), is not necessarily challenged in the same way, since on the epistemological view natural kinds are embedded in scientific practices in a way that makes the posterior reference to science irrelevant.

[20]This parallel between the history of science and science education is comparable to that discussed by Giere (1990) and Carey & Spelke (1996) on the same subject.

[21]This fact is revealed also in concept learning. As Spelke (1988) pointed out, learning intuitive concepts are constrained by innate principles that determine entities of the mentally represented world, while learning scientific (nomic) concepts involves radical conceptual changes.

Acknowledgments

I would like to thank Keyvan Alasti and Hossein Sheikh Rezaee for helpful discussions on the earlier versions of some of this material. I also appreciate Mahmoud Vahidnia for valuable conversations we had while writing the final version.